Appendix K

Hydrologic Depletion Analysis of the Effects of Changes in Points of Diversion on Water Elevations and Land Cover Types

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K.1 Introduction

Future potential water transfers along the lower Colorado River (LCR) will result in changes in the quantity of water diverted at various points on the River. During the next 50 years, up to 1.574 million acre-feet annually (mafy) of water that is currently diverted at points below Parker Dam may be diverted at points above Parker Dam, primarily Lake Havasu or Lake Mead. Of that amount, up to 0.845 mafy could be diverted from Lake Mead. These changes will, in turn, result in changes to the flow and water surface elevations in the River and connected backwaters and to groundwater levels adjacent to the River that lie under riparian, marsh, and isolated backwater areas. Appendix J documents the results of analyses performed to determine the changes to water surface elevations in the River resulting from these diversion changes, while this appendix documents the impacts to the River and connected backwaters, and to groundwater elevations that are influenced by the River that could affect riparian, marsh, and isolated backwaters.

Flow reductions from changed points of diversion will have no measurable effect on the distribution of daily water releases for hydropower production from Davis and Parker Dams. These releases will continue to be made according to established operation guidelines as described in Section J.4.3.3 of Appendix J. However, the hourly distribution of releases may be affected, as shown in Appendix J, Section J.6.2 and Attachment D. For specific mean daily releases, the magnitude and/or duration of the high and low hourly releases may be reduced within the operational minimum, maximum, and rate-of-change constraints. These reductions in the magnitude and durations of hourly releases will result in reductions in flows and river stages down stream of each dam, as shown in Appendix J, Section J.6.2 and Attachment D. The reductions in river stage would affect the available extent of open water, both in the river itself and to connected backwaters. Reductions in annual median river stage could also affect groundwater elevations in areas influenced by the river.

K.2 Methodology

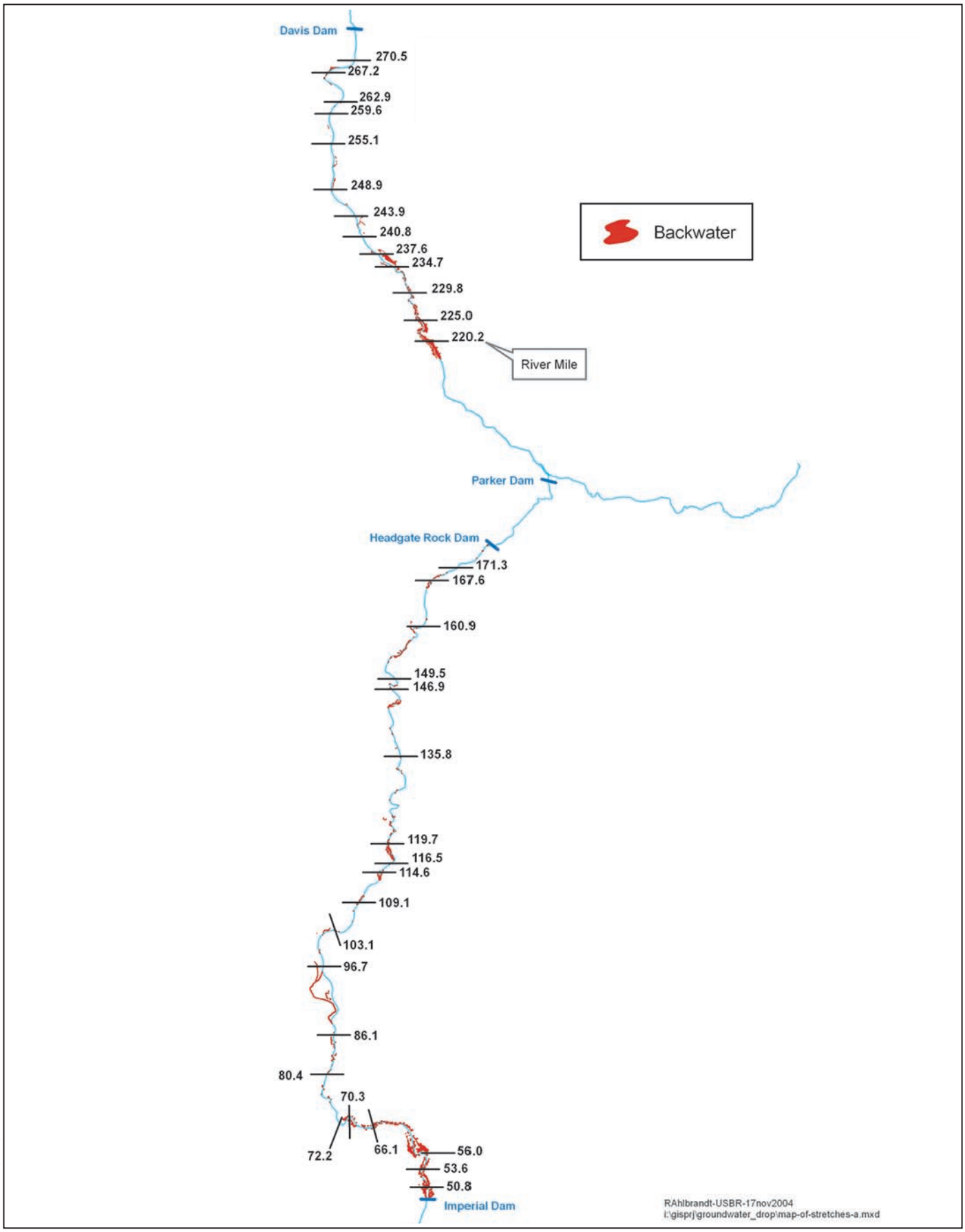
Impacts to aquatic and riparian land cover types resulting from changed diversion points are dependent upon changes to water surface elevation changes in both the River and in backwaters and in groundwater elevation changes where groundwater is influenced by the River. As water surface elevations decrease, the extent of aquatic and marsh land cover types decreases and water levels that support riparian vegetation decrease. This section describes the methods used to determine how much decrease occurs to riverine areas, backwaters and associated marshes, and habitats supported by groundwater.

The following analysis to determine impacts to river surface, backwater and associated marsh, and riparian vegetation is based on the following assumptions:

- Groundwater in the floodplain is directly influenced by the annual median river surface elevation of the river.
- The surface elevation of backwaters not directly connected to the river is equal to the existing groundwater elevation.
- The impact to backwaters not directly connected to the river was derived from the annual median river water surface elevation.
- Riparian vegetation is influenced by the underlying groundwater and therefore could be affected by any change in groundwater.
- The surface elevation of backwaters directly connected to the river is equal to that of the river.
- The impact to directly connected backwaters and associated marshes was derived by assuming that the lowest hourly elevation for the month of April resulted in a permanent change to that elevation.

K.2.1 River Surface

Thirty-three river channel cross-section locations were selected that represent typical river stretches. These locations were distributed throughout the river in order to appropriately cover the entire river between Davis Dam to Imperial Dam. Figure K-1 identifies these locations by River Mile (RM). Selection criteria included river bed slope, geometry, proximity to concentrations of backwaters, and availability of quantitative data. Hydrologic model simulations were used to determine river water surface elevations at each of these cross-section locations. Input to the model included hourly for each calendar month, and average daily releases from Davis Dam and Parker Dam for the river reaches between Davis Dam and Parker Dam and below Parker Dam, respectively. The model output was shown as river water surface elevations resulting from hourly flow releases from Davis and Parker Dams. The model simulations were used to develop tables indicating reductions in water surface elevations at each of the 33 locations—and their corresponding river stretches—resulting from flow reductions that will be caused by future changes in point of diversion. Appendix J contains a detailed description of the modeling process and results.



00450.00 303 (11/04)

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Figure K-1
River Sections Used in Backwater Reduction and Groundwater Drop Analyses

Projected hourly maximum and minimum flows derived from the hydrologic modeling runs were used to define changes to water surface elevations and the resultant effect to riverine, connected backwater and marsh water surface area. A bank slope of 30 degrees was used to determine surface water area changes resulting from water elevation changes (see more detailed discussion below).

Data were developed for flow reductions in three different months—April, August, and December. These months were selected for detailed analysis because of the significant biological activity that occurs during each month. April was selected because that is when the highest flows in the system occur and, therefore, when backwaters, important nursery areas for larval fish, are also at their highest water surface elevation. April also represents the time of new growth and dormancy break for cattail and is also within the Yuma clapper rail breeding season. Backwaters in August are important for juvenile fish cover. December represents the lowest water elevations throughout the year. These three months were used to calculate impacts to backwaters directly connected to the river and to the river surface.

An additional hydrologic model simulation was performed to determine the annual median flow at each of the cross-section locations. River water surface elevations from this simulation were used to determine impacts to groundwater and to backwaters that are not directly connected to the river (see further discussion under Backwater and Groundwater sections below).

Flows derived from the model simulations were adjusted for diversions, gains, and losses, depending upon the month. The "Muskingum Method" developed by the Corps of Engineers (U.S. Army Corps of Engineers 1981) was used to route flows down river from the release point (Davis Dam or Parker Dam). These flows were further calibrated for historical flows at locations where gauges measure the actual river flow. Past experience using this method of calculation has indicated good correlation and reliability of values over a wide range of flow.

K.2.2 Backwaters

Backwaters along the LCR between Davis Dam and Imperial Dam were originally mapped in 1986. In order to reflect more current conditions, that effort was updated in 2000 when the backwaters were inventoried and described by GEO/Graphics, Inc. under contract with the Bureau of Reclamation (Reclamation) (GEO/Graphics, Inc. 2000). Using color aerial photography taken in 1997, a total of 461 backwaters were identified. Although 461 backwaters were identified and characterized, a number of them would either not be impacted by changes in river water surface elevations or were canals, marinas, or other artificial features that support little or no habitat. Once these backwaters were removed from the dataset, the analysis included 380 backwaters. Field verification was conducted by helicopter on April 17, 2000.

A detailed analysis, the backwaters were identified by shape—linear, ellipsoid, and combination, where a backwater had both linear and ellipsoid characteristics—and consolidated into twenty-seven representative backwaters which were selected for detailed surveys. This group included some of each shape because it was originally

thought that bank slopes were significantly different for different shapes. The surveys were conducted using both global positioning system technology and traditional land surveying methods. Survey lines generally included several cross-sections and profiles along the longitudinal and lateral axes.

Analysis of bank slope data from surveys that were conducted on representative backwaters reveal typical bank slopes in the range of 30 to 39 degrees from horizontal. These values closely approximate those documented in the literature as the angle of repose for natural, unconsolidated slopes (Longwell et al. 1969; Bates and Jackson 1980). It was also found that there was little difference in bank slopes of different shaped backwaters. Slopes were also not necessarily consistent on an individual backwater. So, instead of trying to associate specific backwaters or backwater shapes with a particular bank slope, a slope of 30 degrees was used for all backwaters. Use of this flatter slope value of 30 degrees provides a conservative (high end) estimate of impacts contributed by the reduction in surface water area.

For the evaluation of effects to open water and marsh habitat in backwaters, backwaters were characterized by how much open water and how much emergent vegetation each contained. As water levels within the backwater declined, the surface area for the backwater would also decline, and the area of emergent vegetation would also decline.

Backwaters classified as directly connected had a surface water connection leading directly from the River channel. Backwaters classified as indirectly connected are separated from the River and are supported by groundwater. Effects to directly connected backwaters were determined using the hourly river surface analysis and effects to indirectly connected backwaters were determined using the groundwater analysis.

K.2.3 Groundwater

Groundwater adjacent to the river is influenced by the annual median elevation of the water surface in the river. If the river-influenced groundwater elevation declines because of reduction in annual median river elevation, vegetation supported by that groundwater may be impacted. The methodology for determining the area of groundwater influenced by the river and the changes in groundwater table elevation induced by median river elevation changes are presented here.

Riparian vegetation along the river is supported by water from the river. Water is lost (creating a “losing section”) from the river in reaches where there is no irrigation but there are stands of riparian vegetation. This is because there is no input of water to the groundwater from its use on agricultural lands so the use by vegetation induces a water table gradient away from the river. The river is essentially the only source of water for the flood plain riparian vegetation because tributary groundwater inflow is extremely small. The groundwater table elevation at any location in losing sections will be the same as a decline in river annual median river surface elevation. It will take a period of time for the decline in elevation of the groundwater table to stabilize at a decline equal to that of the river because of the slow movement of groundwater, and that is why an annual median reduction in Colorado River surface water elevation was used in determining impacts to groundwater elevations. The small average annual tributary groundwater

inflow, where applicable, and water consumption by riparian vegetation are assumed to remain constant and, therefore, will have no influence on changes in groundwater table elevations.

The river gains water where river water is used for agricultural irrigation on the adjoining flood plain or within the river valley. These sections are defined as "gaining" sections. The amount of water "gained" in these sections is less than the amount diverted upstream for irrigation because of crop consumptive use and evaporation. In these sections the amount of water not consumptively used by irrigated crops or evaporated, percolates down to the water table (deep percolation). This deep percolation raises the groundwater elevation and creates a water table gradient towards the river either directly or through drains. In these gaining sections, near-river groundwater table elevations are influenced by irrigated agriculture as well as water surface elevations in the river.

During the mid-1970s, Loeltz and Leake (1983) studied groundwater conditions in the Yuma area. While the primary purpose of this study was to quantify agricultural drainage flows that return to the river, some of the data from the study can be used to estimate the response in groundwater elevations to changes in annual median river water surface elevations in "gaining" sections since all the effective transects were in agricultural areas. In this study 18 observation well transects were established about one mile apart between Laguna Dam and Morelos Diversion Dam. Each transect consisted of observations wells 100 and 400 feet from the edge of the river on each side. The transects were aligned perpendicular to the river. Results from this study are believed to be applicable to other valleys along the LCR because the geohydrology is similar (see U.S. Geological Survey Professional Papers 486-G, 486-H, and 486-J for a detailed description of the river aquifer from Davis Dam to Yuma). Most of the wells used in this study were destroyed during the 1983 high flows on the river, so are no longer available for data collection.

The first step for determining changes in groundwater table elevations was to mark river annual median river water surface elevation changes at each of the 33 RM locations. Changes to the nearest two-tenths of a foot were then interpolated between the 33 locations and marked along the centerline of the river. At each location of a 0.2-foot increment mark a perpendicular cross-section was drawn through the profile of the groundwater aquifer. In "gaining" sections where groundwater is influenced by irrigated agriculture, the groundwater elevation decline was set at one-half the annual median river water surface elevation decline at the edge of the irrigated field nearest the river, based on data from the Loeltz and Leake (1983) study. Moving away from the river, the groundwater decline was set at zero at a point on the cross-section where the distance from the edge of the field (where the decline was half the river decline) is equal to the distance from the bank of the river to the edge of the irrigated field. As an example, if the annual median river water surface declined by 1 foot, the decline in groundwater elevation was 0.5 foot at the edge of the nearest field on the cross-section. If the distance from the river bank to the field edge was half a mile, then, going along the cross-section away from the river, at a point ½ mile from the field edge the groundwater decline was set at zero.

In "losing" sections, the decline in groundwater elevation was set equal to the annual median river surface elevation decline along the entire cross-section. The rationale for

this is that the only source of water for these areas is the river, and therefore the full reduction to the groundwater would effectively characterize the effect. Once those points were established, contour lines joining points of equal groundwater declines were drawn. The contour lines were digitized and contour maps were developed.

An estimate of riparian, and indirectly connected backwater, acreage influenced by a reduction in annual median river surface elevation resulting from changes in flow was made by overlaying the groundwater decline contour map on aerial photo-based land cover type maps (see BA Chapter 4 and HCP Chapter 3 for descriptions of the land cover types and mapping). Results of this analysis were used to quantify the effects of implementing the future flow-related covered activities on covered species habitats.

K.3 Analysis Results

Results of the modeling described above were used to establish how water surface elevation changes of the river would effect water surface area changes on the river, water surface areas of backwaters connected to the river, and in water table elevations of groundwater influenced by the river. The reduction in area of river, backwaters and associated marsh, and riparian vegetation are illustrated in this section.

K.3.1 River and Backwaters

Impacts for river, directly connected backwaters and associated marsh were determined for three months of the year. The most extreme changes occurred in April (Tables K-1 and K-2). Because of the desire to analyze a worst-case condition, the changes for the month of April were used in the analysis of impacts on covered species habitat.

The following table shows the river area by reach and the reductions in that area for each month that flows were analyzed. The acres of reduction presented for April in these tables were used in defining the effects to aquatic and marsh associated covered species.

Table K-1. Reduction in River Area Acres

Reach	Current River Area (acres)	Reduction in River Area (acres)		
		April	August	December
3	3,585	53	8	0
4 and 5	10,303	137	77	48
Total	13,888	190	85	48

Table K-2. Reduction in Backwater Area

Reach	Current Total Backwater Area (acres)	Reduction in Backwater Emergent Area (acres) [a]			Reduction in Backwater Open Water Area (acres) [a]		
		April	August	December	April	August	December
3	3,289	24	6	0	8	2	0
4 and 5	7,234	109	62	48	68	39	30
Total	10,523	133	68	48	76	41	30

[a] The numbers used for the impact analysis in the Draft LCR MSCP documents have been corrected in these final documents. The change is the result of the correction of an error.

K.3.2 Groundwater

Digitized contour maps showing groundwater table elevation changes are shown in Figures K-2–K-4. The contours are only shown in mapped riparian vegetation areas.

As shown by the contours, the maximum predicted reduction in groundwater elevation is 0.8 feet in Reach 3, 1.6 feet in Reach 4, and 1.2 feet in Reach 5.

For example, Table K-3 shows that groundwater levels could decline beneath 2,008 acres of the cottonwood-willow land cover type. These figures do not reflect the amount of covered species habitat lost as described in the HCP and BA, but are the dataset used in conjunction with the species habitat models (see BA Chapter 4 and HCP Chapter 3) to define the effects to the species.

Table K-3. Potential Reduction in Extent of Cottonwood-Willow Land Cover Resulting From Groundwater Elevation Changes

Cottonwood-Willow Structural Type[a]	Reach			Total
	3	4	5	
I	7	47	66	120
II	13	26	2	41
III	405	394	465	1,264
IV	44	283	63	390
V	42	31	3	76
VI	26	75	16	118
Total	537	855	616	2,008

[a] See Section 4.4.1 of the LCR MSCP BA and Section 3.4.1 of the LCR MSCP HCP for a description of the structural types.

K.4 References

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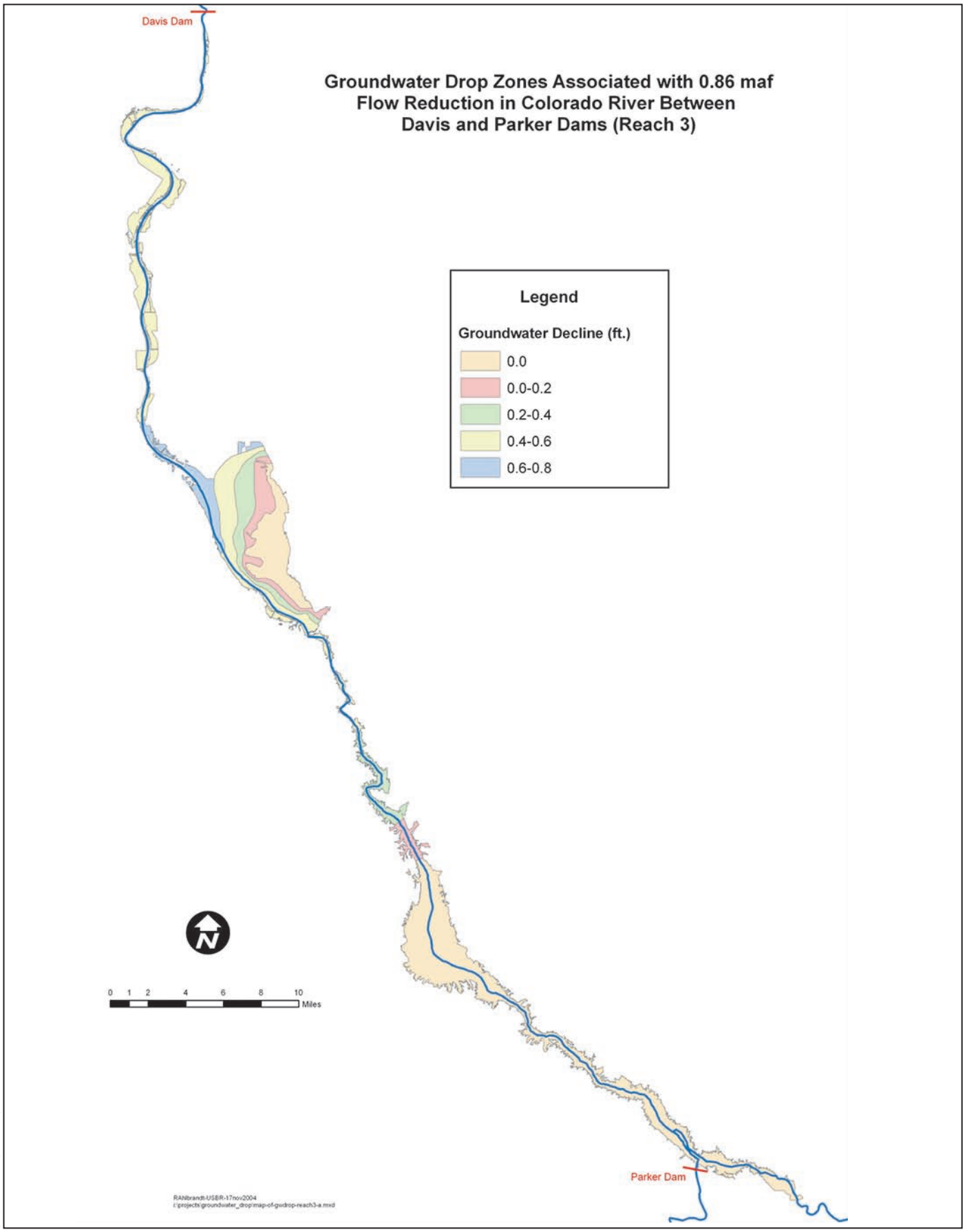

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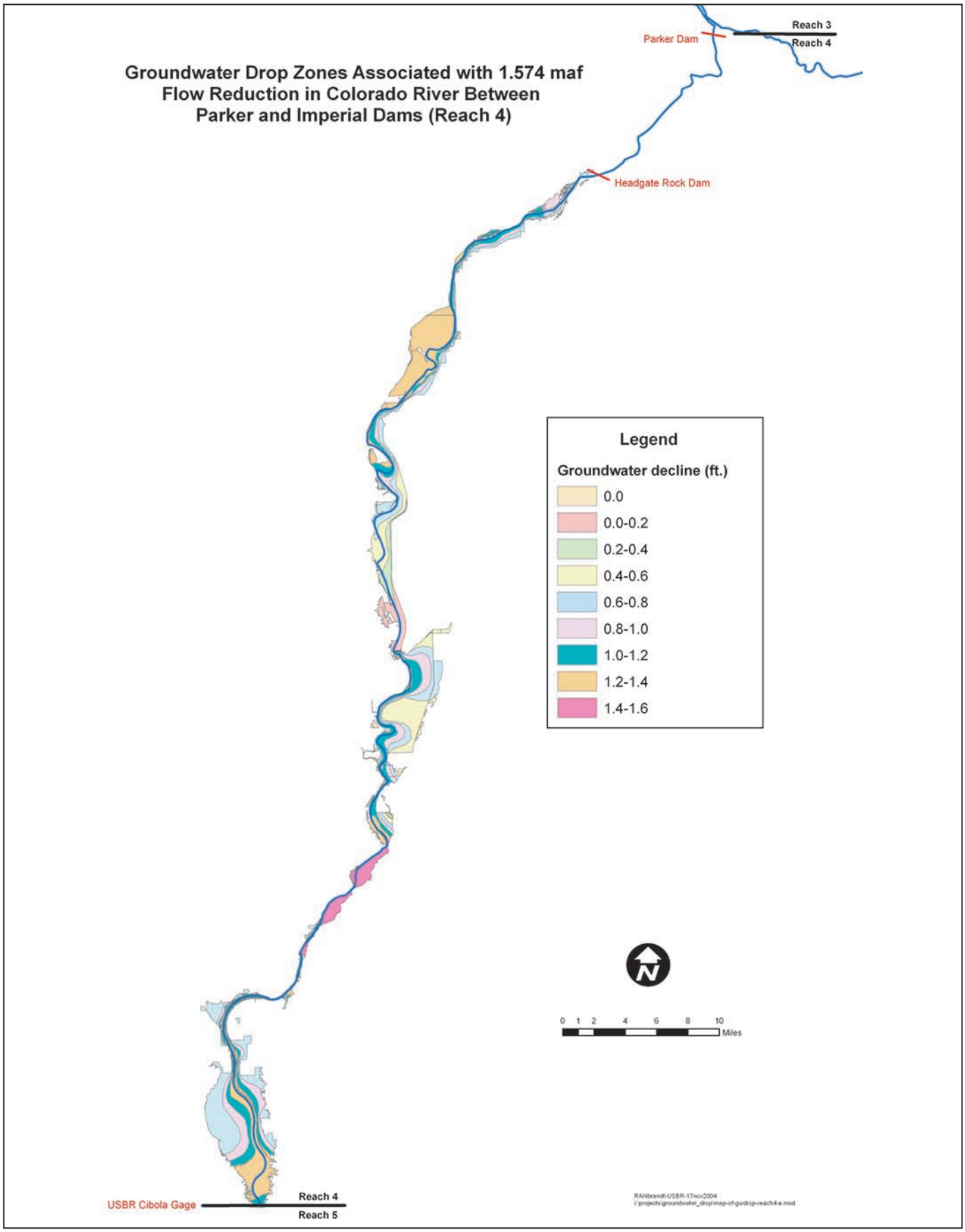
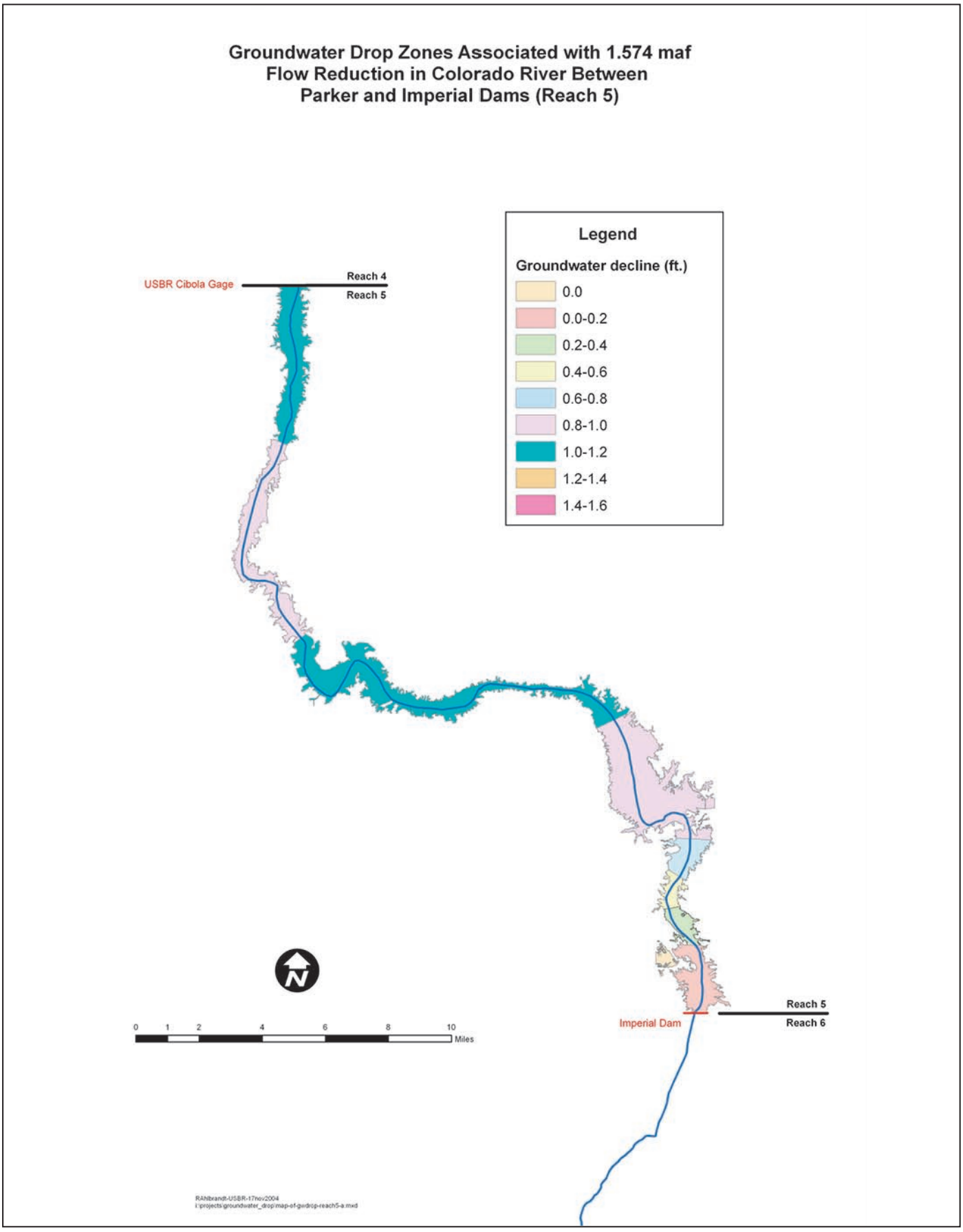
Figure K-2
Groundwater Drop Zones Associated with 0.86 maf Flow Reduction in Colorado River Between Davis and Parker Dams (Reach 3)



00450.00 303 (11/04) Appendix K

Jones & Stokes

Figure K-3
Groundwater Drop Zones Associated with 1.574 maf Flow Reduction in Colorado River Between Parker Dam and Imperial Dams (Reach 4)



00450.00 303 (11/04) Appendix K

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Figure K-4
Groundwater Drop Zones Associated with 1.574 maf Flow Reduction in Colorado River Between Parker Dam and Imperial Dams (Reach 5)